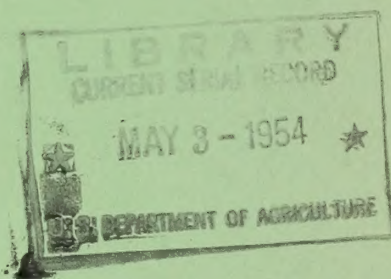


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DWARFMISTLETOE OF PONDEROSA PINE IN THE SOUTHWEST

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INTRODUCTION

Dwarfmistletoe^{1/} has long been recognized as a problem in ponderosa pine management and protection in the Southwest. Research leading to control measures has been in progress at various times since 1908. The first investigations were begun at the Fort Valley Experimental Forest near Flagstaff, Arizona and were summarized by C. F. Korstian and W. H. Long in U.S.D.A. Bulletin 1112 dated December 21, 1922. They show that heavy infections on individual trees caused (1) reduced increment, (2) premature mortality, and (3) reduced quantity and quality of seed crops. G. A. Pearson, in his recent monograph on the management of ponderosa pine (1950) classed dwarfmistletoe along with lightning and wind as one of the three major causes of mortality in merchantable timber. He further stated that heavy infections may reduce increment by as much as one-third and suggested that such losses probably exceed those associated with mortality. Unfortunately there are no reliable quantitative data on the region-wide losses due to dwarfmistletoe but a conservative estimate places them at 6 million board feet annually. They presumably will increase unless some effort is made to curtail them.

Since dwarfmistletoe is a natural component of the vegetation in the ponderosa pine type, it is sometimes regarded as a relatively harmless pest. The viewpoint is perhaps tenable as a broad ecological concept but can hardly be considered a paractical one where a particular infected stand must be preserved and maintained indefinitely for aesthetic or economic purposes. Although dwarfmistletoe does not threaten the existence of ponderosa pine as a species, in certain localities it has rendered stands unproductive, unsightly, and in some cases has favored invasion by woodland-type or other species. The fact that some infected stands have given fair to good yields might also cause one to assume that future yields of the same quantity and quality can be expected. If such were the case, the apparent loss in increment due to dwarfmistletoe might not warrant the cost of special control measures. On the other hand, if one considers the insidious aggressiveness of this parasite it is more likely that once it has built up a sizeable population its effect on yield will be progressively detrimental in the future and will lead eventually to complete loss.

^{1/}The name "mistletoe" refers to the European genus Viscum, while our so-called mistletoes all belong to other botanical genera. The principles of English nomenclature for denoting the common names of plants require under the circumstances a prefix combined or hyphenated with the word "mistletoe" in order to distinguish the North American plants. The name "dwarfmistletoe" in contrast with the more commonly used "dwarf mistletoe" has therefore been adopted.

Where dwarfmistletoe is abundant on a virtually nonproductive area, there is often a tendency to regard the site as being incapable of growing merchantable trees. In view of the fact that this pest must become established initially on fairly vigorous hosts in order to develop and perpetuate itself, it seems more likely that site may be secondary in such cases and that one is actually witnessing the ultimate in destruction by dwarfmistletoe.

Our observations indicate that dwarfmistletoe is most abundant on ridge or level sites characteristic of open, but nevertheless merchantable, stands yielding up to 10,000 ft. b.m. per acre. It is common on slopes, less common in bottoms, and extremely rare on submarginal sites outside the commercial range of ponderosa pine.

In the subsequent paragraphs an attempt has been made to present information on dwarfmistletoe which will assist in controlling it in those stands where it is regarded as a problem in management or protection programs. Much of this information has been developed from studies in progress at the Fort Valley Experimental Forest since 1933, a detailed account of which has been submitted for publication in the Journal of Forestry. Certain classic facts available in text books of forest pathology have also been used to clarify the following discussion.

DESCRIPTION OF THE PARASITE

The dwarfmistletoe attacking Pinus ponderosa var. scopulorum Engelm. in the Southern Rocky Mountain and Southwestern States is Arceuthobium vaginatum forma cryptopodum (Engelm.) Gill. It is distinct from and more aggressive than A. campylopodum Engelm. forma campylopodum, which is found on ponderosa pine (Pinus ponderosa Laws.) to the west and north. The increased aggressiveness may be due in part to the nature of the dwarfmistletoe species, to greater susceptibility of the scopulorum variety of ponderosa pine, and to the arid climate of the region, which is favorable to a number of related parasites. In any event, the situation in ponderosa pine is considerably more acute in the Southwest than elsewhere within its range.

Flowers

Dwarfmistletoe is dioecious, i.e., the male or pollen-producing flowers are borne on one plant; the female or seed-producing flowers are borne on another (Fig. 1). The flowers bloom in May or June. Pollination is effected by insects. Several crops of flowers may be produced on a single shoot.

Fruits and Seeds

Fruits require 15 to 16 months to mature, ripening in late July or early August of the year following pollination (Fig. 2). They have

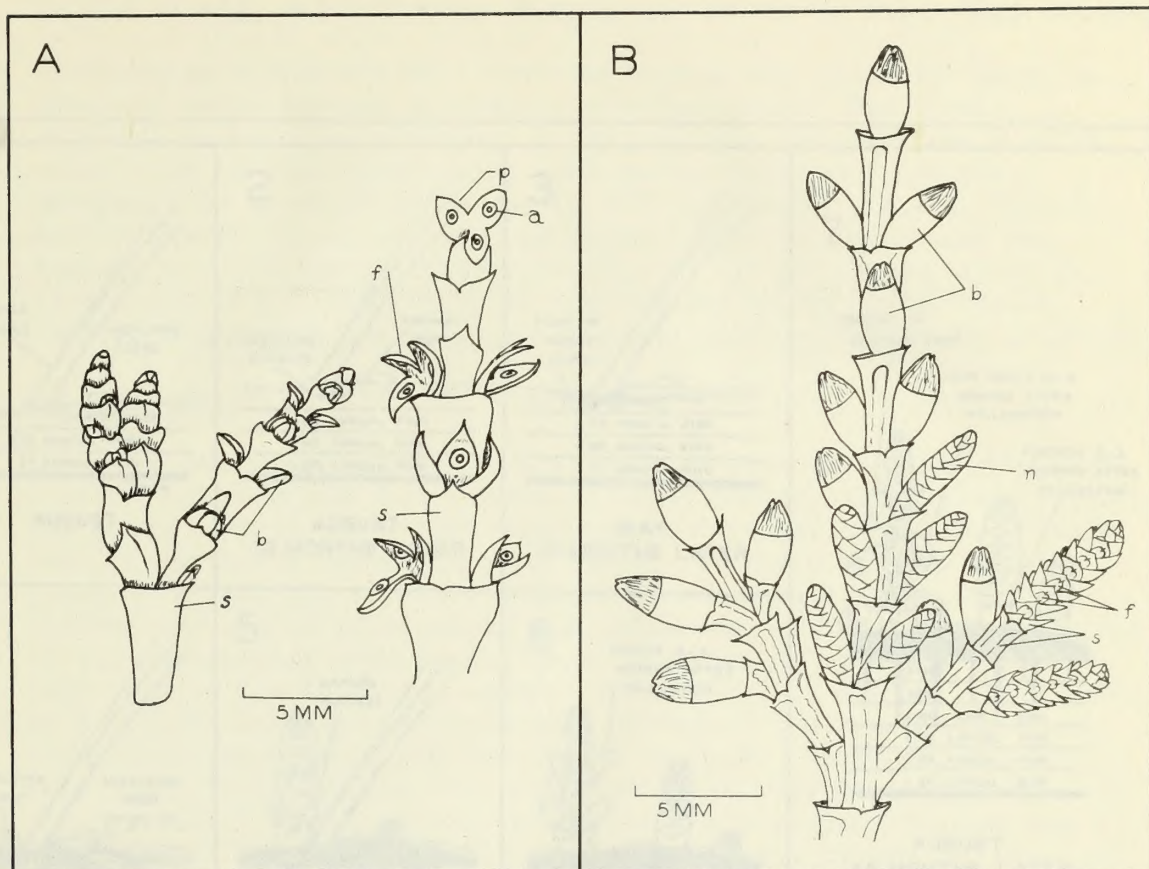


Figure 1.--Floral shoots of *Arceuthobium vaginatum*. A. Male shoots, showing closed flower buds b, borne in the stem segments s, and open flowers f, comprised of 3 (rarely 4) petal-like structures p, each bearing a sessile circular anther a. B. Female shoot, showing flowers at pollination time f, borne in the stem segments s, immature fruits b one year after pollination, and new shoots n on which flowers will be borne next year.

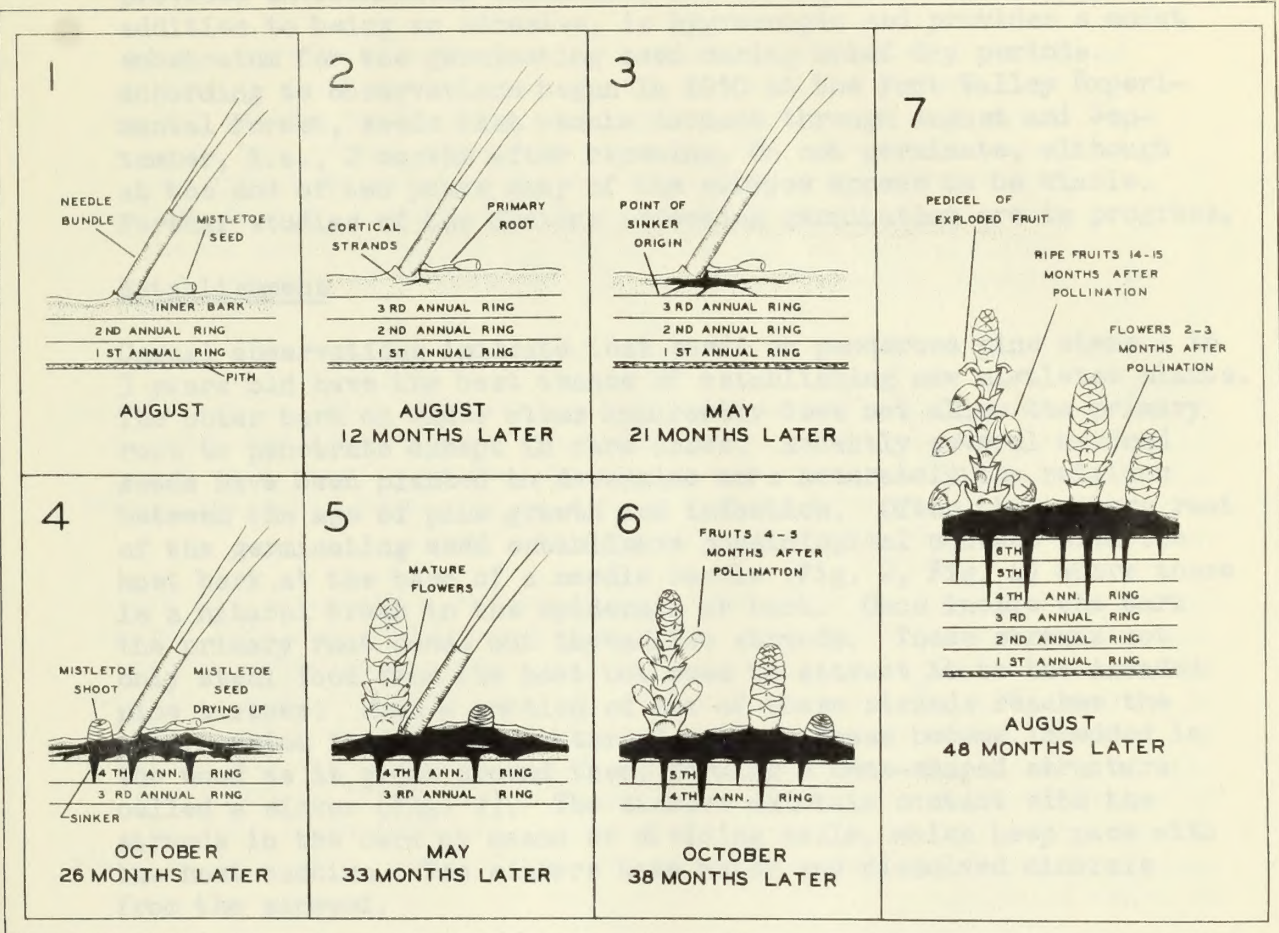


Figure 2.--Diagrammatic sketch, showing the absolute minimum time required for the development of a female plant of *Arceuthobium vaginatum* on a pine twig. (1) Recently expelled seed in place near needle bundle. (2) Twelve-month-old seed after germinating and invading host bark tissues. (3) Twenty-one-month-old seed with absorbing system well established in host bark. (4) Mistletoe plant 26 months after seed matured, showing first shoot bud and sinkers; the seed that prior to this time had supplied some food is now dried up and of no further use. (5) After 33 months the bud has elongated into a flower-bearing shoot. (6) After 38 months the original shoot bears half-ripe fruit and new shoots are developing. (7) After 48 months (about 15 months after pollination) the first fruits are ripe. In general the cycle will take five years or longer.

an explosive mechanism, which expells the single seed forcibly into the air (Fig. 3). The seeds are covered with a sticky substance called viscin, which fastens them to any object on which they alight.

Germination occurs within a few weeks after the seeds are expelled, provided environmental conditions are favorable. The viscin, in addition to being an adhesive, is hygroscopic and provides a moist substratum for the germinating seed during brief dry periods. According to observations begun in 1950 at the Fort Valley Experimental Forest, seeds that remain dormant through August and September, i.e., 2 months after ripening, do not germinate, although at the end of two years many of the embryos appear to be viable. Further studies of the factors affecting germination are in progress.

Establishment

Casual observations indicate that seeds on ponderosa pine stems 1 to 3 years old have the best chance of establishing new mistletoe plants. The outer bark on older stems apparently does not allow the primary root to penetrate except in rare cases. Recently several hundred seeds have been planted to determine more accurately the relation between the age of pine growth and infection. Often the primary root of the germinating seed establishes physiological contact with the host bark at the base of a needle bundle (Fig. 2, Fig. 4) where there is a natural break in the epidermis or bark. Once inside the bark the primary root sends out threadlike strands. These strands not only steal food from the host but seem to attract it to the invaded pine tissues. When a portion of one of these strands reaches the pine cambium it forms a cluster of cells. These become imbedded in the wood as it grows around them, forming a cone-shaped structure called a sinker (Fig. 2). The sinkers maintain contact with the strands in the bark by means of dividing cells, which keep pace with the host cambium. The sinkers take water and dissolved minerals from the sapwood.

After the dwarfmistletoe is well established in the pine the strands in the bark form buds. The buds push through into the open to form shoots (Figs. 1 and 2). The first shoots appear near the point where the primary root entered the host. The later ones follow the advancing front of the absorbing system and may in time appear well away from the point of origin. They are perennial and may become 12 to 14 inches long before they die. The shoots arising from an absorbing system that originated from a particular seed are all of the same sex.

Life Cycle

Observations on "planted" seeds at Fort Valley (Fig. 2) indicate that:

1. The shortest period between the time a seed alights on a pine stem and the first shoot buds appear is 26 months.

2. At least 33 months are necessary for the production of readily recognized shoots bearing flowers.
3. A minimum of 48 months must elapse before the first crop of fruits can possibly be produced. In general the cycle will take five years or longer.
4. There is indirect evidence that many dwarfmistletoe plants will remain invisible or latent much longer than 26 months. A few apparently will not produce their first shoots for 10 years or longer. The tendency to remain latent has an important bearing on control in that it is impossible to cut out all mistletoe in a single operation. Recent studies indicate that of the infections appearing 10 years after control, about 80 percent will be visible in 6 years.

Means of Spread

Spread is generally effected through the explosive force of the fruits. By this means new dwarfmistletoe plants are continuously being established higher and higher in the crowns of infected trees (Fig. 3); otherwise the parasite would tend to die as the lower limbs are shaded out before the absorbing system invades the trunk.

Spread to new trees is most effective where the seeds pass from overstory to understory (Fig. 5). An infected overstory tree will broadcast dwarfmistletoe into the surrounding understory within a radius of 60 feet (Fig. 6). A few seeds are shot greater distances. In one-storied stands the spread to new trees is very slow since only trees adjacent to infected ones are exposed to the seed barrage and these in turn must have time for dwarfmistletoe to develop well in their own crowns before they menace their neighbors. Isolated new infection centers presumably arise when seeds are carried long distances by birds or other animals.

Effect on the Host

In addition to having an adverse effect on the physiology of the host, dwarfmistletoe is also responsible for certain physical abnormalities. The first apparent effect is a tendency on the part of the invaded pine tissues to become swollen. Initially this is little more than an increase in thickness and succulence of the inner bark. Later, when the parasite becomes well established, there is also local accelerated growth of the affected wood. In the case of main limbs, the acceleration often occurs between the mistletoe infection and the trunk and results in such abnormal taper that the limbs are almost carrot-shaped. As the infection progresses the normal symmetry of branching is destroyed, leading eventually to a concentrated cluster of twigs with huge bases and fine tips. The abnormal structures are known as witches'-brooms (Fig. 7, A and B). The foliage on vigorous

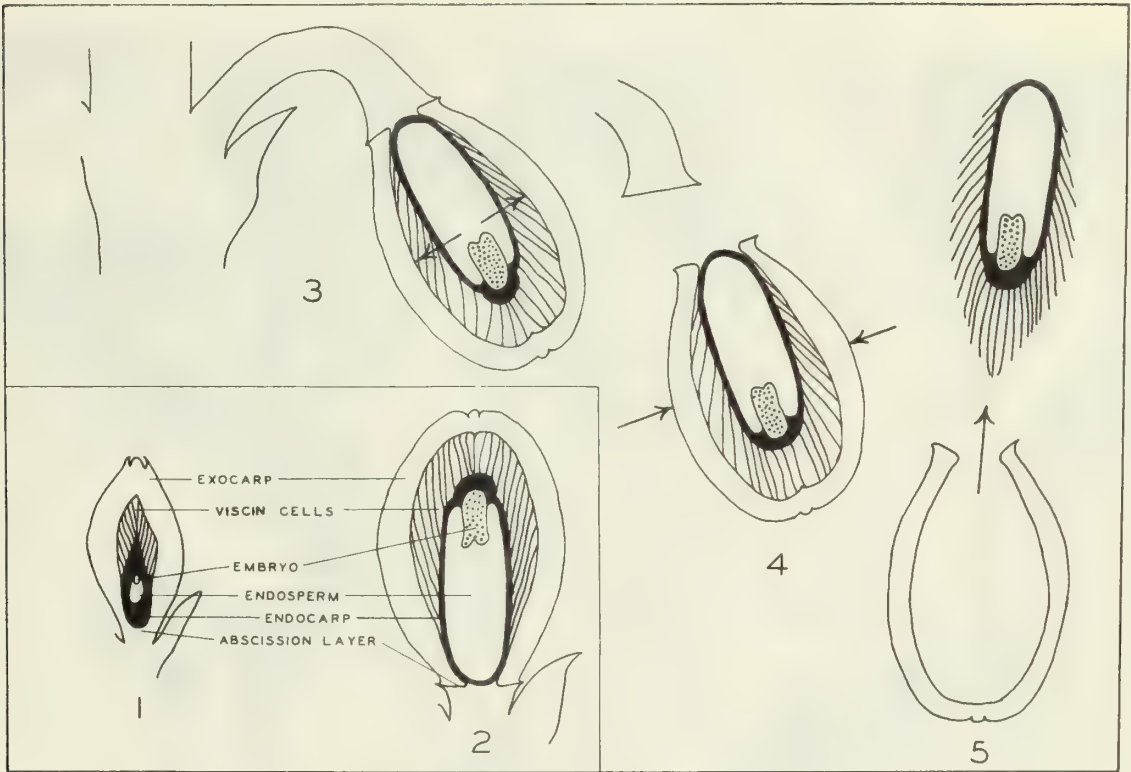


Figure 3.—Explosive mechanism of *Arceuthobium* fruit. (1) Basic tissues in immature fruit, (2) basic tissues in nearly mature fruit, (3) mature fruit with stem curving downward. Hydrostatic pressure from water absorbed by the viscin cells stretches the exocarp. (4) Hydrostatic pressure inside the elastic exocarp has caused it to break away from its base at the relatively weak abscission layer. (5) With the pressure released the exocarp contracts violently and expells the seed upward into the air.

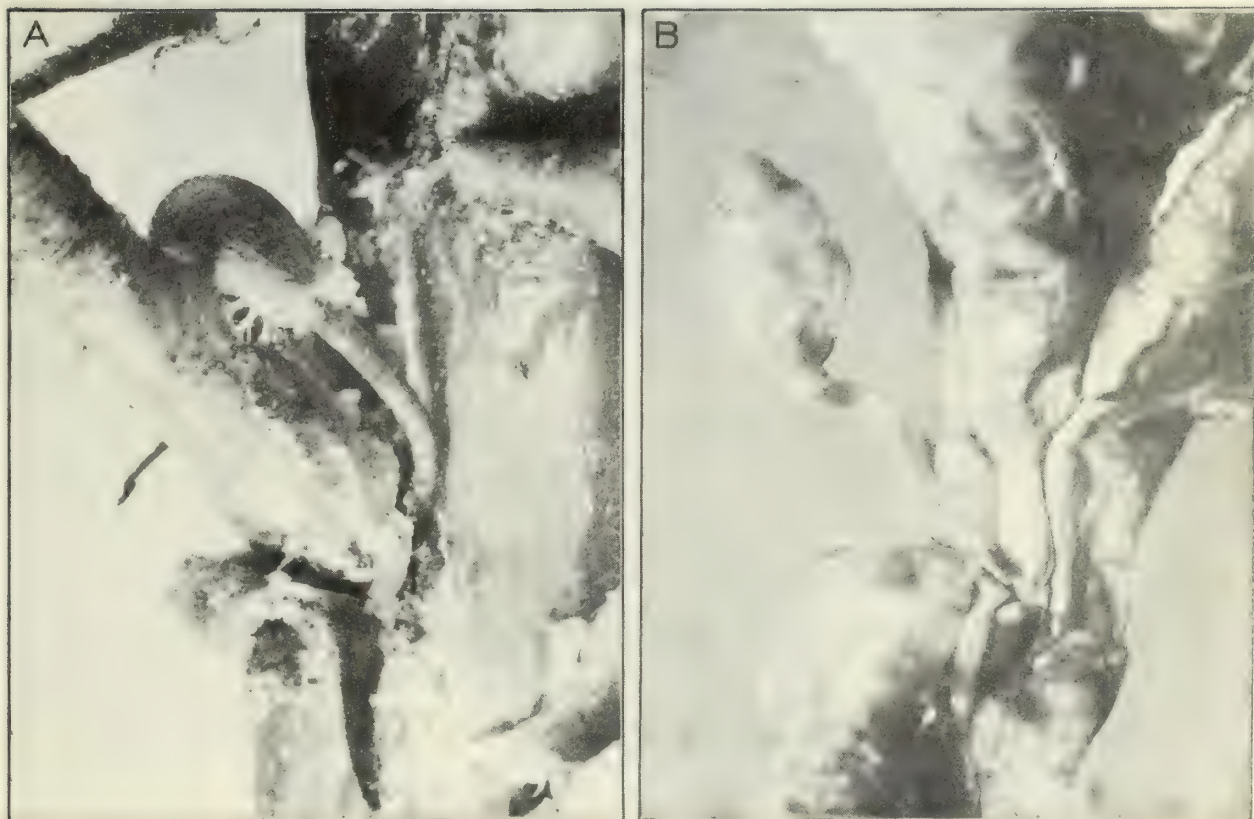


Figure 4.—Germinating seeds of Arceuthobium vaginatum. A. Seed in place two months and germinating at the base of a needle bundle on a 3-year-old ponderosa pine stem. The tip of the primary root is hidden under the base of the needle bundle. Strings of viscin are holding the seed to the needle sheath. B. Seed in place 1 year, showing the development of a holdfast at the end of the primary root, which has been exposed by bending back the needle bundle. Primary absorbing strands have penetrated the host cortex from the holdfast.

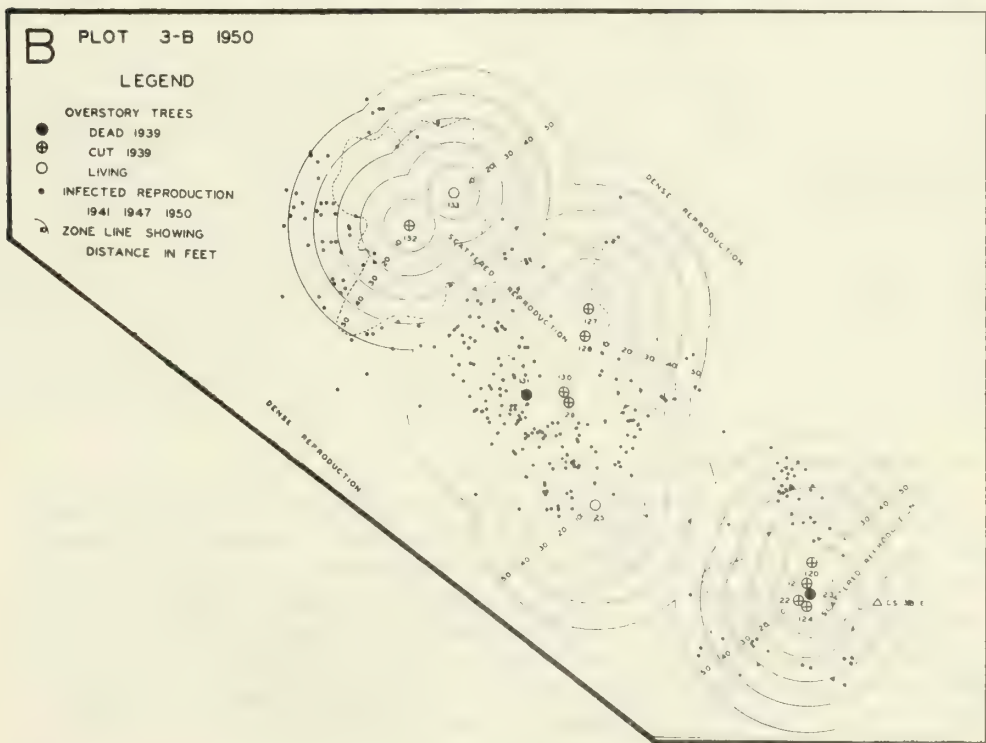


Figure 5.—A. Ponderosa pine reproduction exposed to a heavy barrage of mistletoe from infected overstory trees (stumps in foreground) for the first 20 years of its life. B. Pattern of infection that developed in the reproduction in the area shown in A. Of the infected seedlings plotted (10 years after the overstory had been removed), 93 percent were infected from the overstory trees and 7 percent had acquired mistletoe from their neighbors.

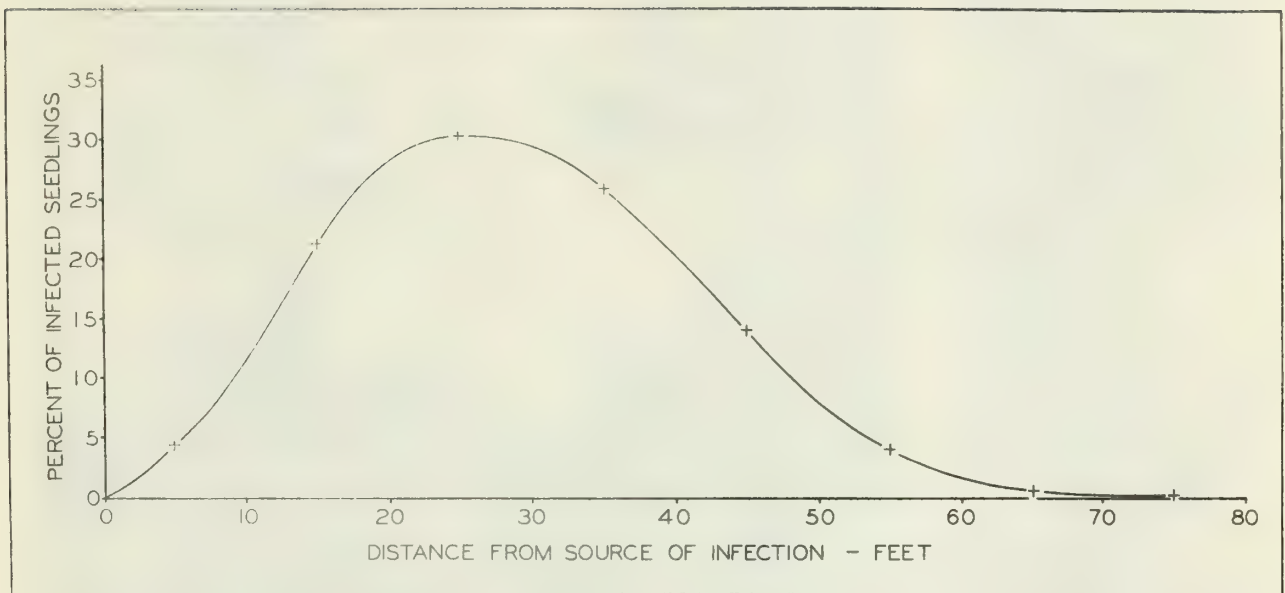


Figure 6.--A frequency curve showing degree of infection in small reproduction in relation to distance from infected overstory trees. Distances were measured from the centers of the overstory trees whereas the mistletoe seed source was usually at the edge of their crowns; the average flight of the seeds is therefore somewhat less than the curve implies. The very light infection in the first 15 feet is explained in part by the fact that the reproduction was much less dense immediately under the crowns of overstory trees. (See Fig. 5)



Figure 7.--Effects of dwarfmistletoe on ponderosa pine. A. Living witches'-broom in lower crown of large pole; in all probability this abnormality will persist long after the normal crown above it has receded. B. Dead witches'-brooms, showing branch malformation caused by a long-standing infection. C. Bole canker, probably the result of dwarfmistletoe absorbing strands entering the trunk through an infected branch after the tree had attained a fair diameter; trunk infections in small trees are often lethal or result in hopeless deformity. The wood included in trunk cankers is pitch-soaked and brashy.

witches'-brooms is considerably more dense than in the normal uninfected parts of the crown. Broomed branches tend to live longer than normal; it is not uncommon to see an isolated witches'-broom with dense vigorous foliage many feet below the rest of the crown. In such cases the base of the supporting limb may attain a diameter 3 to 5 times greater than others on the same whorl which were shaded out naturally. Pruning off large brooms will often increase the vigor of the remaining crown.

Direct infections of the leader are likely to result in death or stag-headedness. However, when the absorbing strands of the parasite, originating in a limb, invade the lower bole of the larger pole-sized trees, both host and parasite often live for long periods. The end result of such a condition is usually a trunk canker illustrated in Figure 7, C. The wood included in such cankers is pitch-soaked and brashy. Few shoots are produced from old bole infections so that while such trees are poor in wood quality they are least hazardous from the standpoint of spreading mistletoe.

CONTROL

Natural Control Factors

In unmanaged forests, fire probably was an important factor in checking the spread and development of dwarfmistletoe. Porcupines are also known to eat the shoots in large quantities for winter food. In addition, they frequently gnaw the succulent infected bark and in so doing may destroy many established plants by killing the branches on which they occur. Squirrels also probably act as natural checks against this parasite but little is known about the exact role they play. Both fire control and rodent control may, therefore, favor dwarfmistletoe intensification.

A number of insects are injurious to dwarfmistletoe. Spittlebugs are among the more common and best known. At times these insects may kill large numbers of shoots in a particular area and thus deter the spread of the parasite. Observations on "planted" seeds indicate that considerable damage is caused by small weevils and other insects, which either destroy or devour the embryo. At times ants may carry off entire seeds. Presumably management and protection practices will not affect these insects except perhaps in limited areas where insecticides are used to control other pests.

Certain fungus diseases are known to hold a number of species of Arceuthobium in check but unfortunately the fungus diseases attacking A. vaginatum of our southwestern ponderosa pine are too few and too weak to be regarded as control agents.

Chemical Control

In recent years there has been some work done on the control of dwarfmistletoe by chemicals. Sprays of various formulations of 2,4-D when applied to dwarfmistletoe shoots are known to be fatal without apparently harming the host. Our experiments with the above-mentioned sprays indicate that while a current crop of shoots may be readily killed in this manner, the absorbing system is not harmed and new shoots are soon produced. Work of this nature has been limited to preliminary tests and as yet no information is available regarding the effect of repeated applications, which might conceivably kill the absorbing system. In Australia, trunk injections of the 2,4-D hormones are reported as successful in killing a closely related parasite (Loranthus) on Eucalyptus. Our own work on chemical control was expanded in 1953 to include both sprays and injections, but results are not yet available.

At the present time it appears that chemical control, if successful, would find its greatest use in the preservation of individual trees or small groups in parks, recreation areas, and administrative sites. Conceivably it might be a valuable supplement to control on large areas, either where infection was very light or in following up a mistletoe reduction program in which logging and timber stand improvement were the principal means used to attack the parasite.

Physical Reduction

Physical removal of dwarfmistletoe by cutting, poisoning, or pruning infected trees is the most feasible method of control at present.

In managed stands of sawtimber size removal from the overstory is the first step in control. This may be accomplished by marking as many infected merchantable trees as possible, consistent with silvicultural principles and management policies. At heavily infected centers, which seldom exceed 5 to 10 acres, little or no good will be effected from a sanitation standpoint without departing from the usual residual volume limits and age-vigor concepts. Heavy cutting will be inevitable and too often the trees that are the most hazardous as perpetuators of mistletoe are among the youngest and best risk classes. As many unmerchantable infected trees as possible should be cut under the Sanitation Clause in the course of the logging operation.

In the case of aesthetic, recreational, or administrative sites, pruning of large high-value trees may be warranted both as a means of improving the vigor of the treated trees and of protecting the surrounding growing stock. In some costly special-use sites, where dwarfmistletoe was abundant and overstory trees were scarce, pruning has been limited to the removal of female plants only as a means of preserving a canopy and at the same time protecting growing stock.

The treatment of pole-sized stands is essentially a timber stand improvement measure, although the direct cost may sometimes be offset

in part by the sale of infected trees for poles, posts, and other intermediate products. The dwarfmistletoe is removed by felling, poisoning, or pruning.

In general, pruning should be avoided where a tree has numerous clumps of dwarfmistletoe shoots scattered throughout its crown. Such trees usually carry many latent infections, which will appear after the operation (Table 1). One whorl above the highest infected limb should, if possible, be pruned in order to eliminate most of the latent infections. Where shoots appear on a limb within 1 foot of the bole the parasite is probably established in the bole and cannot be eliminated without destroying the tree. This "safe distance" is a rule of thumb based on observations of a few branches of the type ordinarily pruned in pole-sized trees. Studies are in progress whereby it may be judged more accurately according to branch and tree size. In cases where an infected limb is pruned after the absorbing strands have entered the bole, mistletoe shoots will often appear within a year or two on the callus tissue of the pruning wound.

Table 1.--Results of Pruning Dwarfmistletoe Infections on a 1.375-acre Sample Plot (303 Stems Alive in 1950)^{1/}

Tree size class		: Condition and treatment :							
		: 1933 or 1938 :							
		:With mistle-:No mistletoe : Condition							
		:toe. Pruned :Not pruned : all trees							
		:Condition in: Condition in: 1950							
		: 1950 :		: 1950 :					
Nominal	: D.b.h.	: of stems	:With : No	: With : No	: With : No	:With : No	:With : No	:With : No	:With : No
	: in.	: %	: %	: %	: %	: %	: %	: %	: %
Merch.	: 11.6+	8	12	46	5	37	17	83	
Large	: poles	: 7.6-11.5	27	11	25	4	60	15	85
Small	: poles	: 3.6-7.5	47	6	17	2	75	8	92
Saplings	: 0-3.5	18	2	16	0	82	2	98	
Total	: -	100	7	21	2	70	9	91	

^{1/}The two control operations removed 32 percent of the original stems. Of the trees remaining in 1950, 28 out of every 100 had dwarfmistletoe prior to 1938 and were pruned. Of these, 7 (25%) subsequently developed dwarfmistletoe, whereas 72 out of each 100 were not infected prior to 1938, were not pruned, and only 2 (less than 3%) developed dwarfmistletoe in the 12- to 17-year period.

Treatment of stands below small pole size can seldom be justified except on special-use sites where frequent pruning can be done. Where small reproduction has become infected, dwarfmistletoe control could best be delayed for 10 years or more after removal of the infected overstory. During this period the parasite will intensify on infected trees but will not spread appreciably to new ones. Furthermore, there will be some mortality among trees with mainstem infections and many minor branch infections will be eliminated by shading out.

When all apparent dwarfmistletoe is removed from a stand there always remain a number of latent infections that were established before the control operation. These will subsequently manifest themselves for several years. If the new shoots were cleaned out at 2-year intervals for the first 6 years following control all but a few stragglers would be eliminated. Because of the two seasons needed to mature fruits, no new infections would occur during the period. Control operations of such intensity would not be feasible or necessary to effect drastic reductions. Our studies on a 12-acre plot at Fort Valley indicate that one follow-up operation 5 years after the original control work should be effective in reducing dwarfmistletoe to a negligible loss factor for more than 20 years, and presumably much longer. With a conscious policy of attrition it could be kept under control indefinitely by regular intermediate cuttings after the major part of it has been removed.

Justification for Control in Managed Forests

The departures from normal management or protection policies plus modified timber stand improvement operations required for mistletoe control appear to be justifiable even though they may create some problems in regeneration, sustained yield, soil deterioration, and slash disposal with its attendant fire and bark beetle hazard. Without control, production is bound to decrease, new growth will become infected at progressively earlier ages, there will be heavy mortality between normal cutting periods, and in time production will be nil in the infection centers. In addition, outbreaks of other diseases or of bark beetles may result. A decision to use control measures, therefore, hinges on the value of maintaining future production at some sacrifice of current wood capital and growing stock.

One additional feature of control, which warrants some speculation, is its possible effect on inheritance. Some trees appear to have natural resistance to dwarfmistletoe. While nothing is known of the genetics of such resistance, it is possible that the artificial elimination of susceptible trees as breeding stock will favor the production of resistant strains in greater proportion than would otherwise occur.

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